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RESEARCH ARTICLE

Study on the Coupled Human – Natural System in Velingrad municipality, Bulgaria: a resilience perspective

Elena Todorova, Miglena Zhiyanski

Forest Research Institute, Bulgarian Academy of Sciences, 132, "St. Kliment Ohridski" Blvd.1756 Sofia, Bulgaria

Corresponding author: Elena Todorova (elenatyukenova@yahoo.com)

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Abstract

The study presents a new look on the socio-ecological relations in retrospective, focusing on their formation and adaptation over time in Velingrad Municipality, Bulgaria. The dependencies between the main components of the system are outlined and the main disturbances in terms of presses and pulses are examined. Examples of trade-offs and synergies are also offered to better understand the cross-scale dynamics of the studied components. The reaction of the system to pulses in its growth phase of the adaptive cycle is reviewed. In addition, the contemporary state of the main components of the coupled human-natural system is analysed in order to identify the slow and fast variables that determine the trajectory of the system at present. The resilience thinking concept is applied in analyzing the processes within the coupled human-natural system and in identifying the mechanisms that may enhance its capacity to absorb shocks.

Keywords

social-ecological systems, variables, resilience, adaptive cycle

Introduction

Humans have continuously interacted with natural systems, resulting in the formation and development of coupled human and natural systems (CHANS) (Liu et al., 2007). The pathways of change of the coupled human–environment systems are formed by continuous, dynamic interactions among numerous changing factors, social as well as

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biophysical, which enable and constrain human choices of resource management strategies (Haberl et al., 2016). Using combined social and environmental perspectives to understand how people and wildlife are interlinked, together with the mechanisms that may weaken or strengthen those linkages, is of utmost importance (Carter et al., 2014). CHANS science uses a holistic approach to integrate patterns and processes that connect human and natural systems, as well as within-scale and cross-scale interactions and feedbacks between human and natural components of such systems (Liu e al., 2021)

Drivers of different origin – both endogenous and exogenous affect these interactions, and some scientists consider the exogenous more influential (Bruley et al. 2021). Climate change is the external driver influencing all factors at once and making the ecosystems more vulnerable. Furthermore, conserving wildlife while simultaneously meeting the resource needs of a growing human population is a major sustainability challenge (Carter et al., 2014). Ecosystem services provide regulating, provisioning, supporting, and cultural benefits for human survival, but clarification is needed how the trade-off/synergy relationships can be used to optimize function (Deng et al., 2023). Otherwise, the conjunction of social and environmental events contributes profoundly to the production of trap processes (socio-ecological traps) (Boonstra et al., 2014). Human activity as an agent of change, and thus of the environmental dynamics (Gonzalez et a., 2014). Therefore, a deeper understanding of the correlations of these dynamics and the trade-offs in the ecosystem are needed to support management of ongoing changes and reduce socio-ecological traps.

Liu et al. (2007) distinguishes the interactions within a CHANS, categorizing them into direct and indirect interactions that form a complex web that leads to positive and negative effect in both human and natural systems as well as unique properties not belonging to human or natural systems separately but emerging from the interactions between them. Emergent properties are cornerstones for comprehending human – ecosystem interactions in ways that provide insights for sustainable development (Marten, G., 2001). Untangling complexities, such as reciprocal effects and emergent properties, is essential to developing effective policies for ecological and socio-economic sustainability. The emergent properties within the CHANS suggest that it possesses its own homeostasis and mechanisms for reaching balance, the way the natural ecosystems do (Liu et al. 2007). This resonates with the resilience concept i.e. – the capacity of a system to absorb disturbances and still retain its basic function and structure (Walker and Salt, 2006).

Each society has its own perception of its metabolism with nature (Gonzalez et a., 2014). Hence, looking for answers to these questions in the communities that rely on local resources seems reasonable. Most local communities that have been in one place for long periods of time have developed mechanisms for protection of ecosystem services (McMichael et al. 2005). Apart from that, investigating the way these relationships evolved over time and how the trade-offs behaved under different stressors could be a source of information to build the scenarios. History shows that the human well-being, and indeed the persistence of civilizations, is strongly interlinked to the capacity of the environment to continue deliver ecosystem services at the local and

regional scale (McMichael et al. 2005). In Bulgaria these relations have undergone numerous transitions in time. In historical aspect, the country is an example of a strong dependency and relation to the natural resources while periods of overexploitation of such resources (forests in particular) are followed by restoration and management as well (Boev, 2021). In the Rhodope mountains, the importance of material benefits from forests has traditionally been high and are still significant for the development in the region. Forests are crucial to the preservation of the existing potential of landscape functions (Borissova et al. 2015). Therefore, analyzing forest landscapes as socio-ecological systems is of great importance for resilient management (Fisher, 2018) and is considered as fundamental at regional context in present study.

The study deals with the relationships within a CHANS, built on very straightforward and strong connections between society and environment. That makes the correlation easier to follow. This paper focuses on the formation, adaptation and dependencies between the main components of the system in a retrospective. The cross-scale dynamic is examined by looking for examples of trade-offs and synergies that formed over time and the reaction of the CHANS to disturbances in terms of presses and pulses (Collins et al., 2011). The retrospective study allows looking at the system from resilience perspective and following its transformation in the different phases of its adaptive cycle (Salt and Walker, 2006). In addition, the contemporary state of the main components of the coupled human-natural system is analyzed to outline the slow and fast variables that determine the trajectory of the system nowadays. In this regard an analysis of the trends in the basic demographic, economic, social, and ecological parameters is performed covering the period 1985-2023. The main objective of the study is to better understand the processes and interdependencies within the coupled human-natural system and to identify the mechanisms that may enhance its capacity to withstand shocks. With this regard the study reflects on the human-ecosystem relationships that formed over time and the transformation they experience currently by investigating the dynamics of system's key components and their reactions to disturbances in the past.

Materials and methods

The region of investigation is Velingrad municipality, situated in the western Rhodope Mountains in Bulgaria. The study area covers a territory within the altitude range 750 – 2186 m asl. The forests cover 83,46% of the territory of the municipality (National Statistical Institute, 2021) with dominated by *Pinus sylvestris* plantations – 35% (Forest management plan, 2018), managed traditionally since the beginning of the XIX century (Tsanov, 2014). The regional center is town of Velingrad (20031 inhabitants in 2022, National Statistical Institute) with 20 smaller villages (32270 inhabitants in 2022, National Statistical Institute). Velingrad is located in the Chepino basin, which is in the lowland at about 800 m asl, while the villages are mostly scattered in the higher parts of the mountain. The population in the villages has very distinct cul-

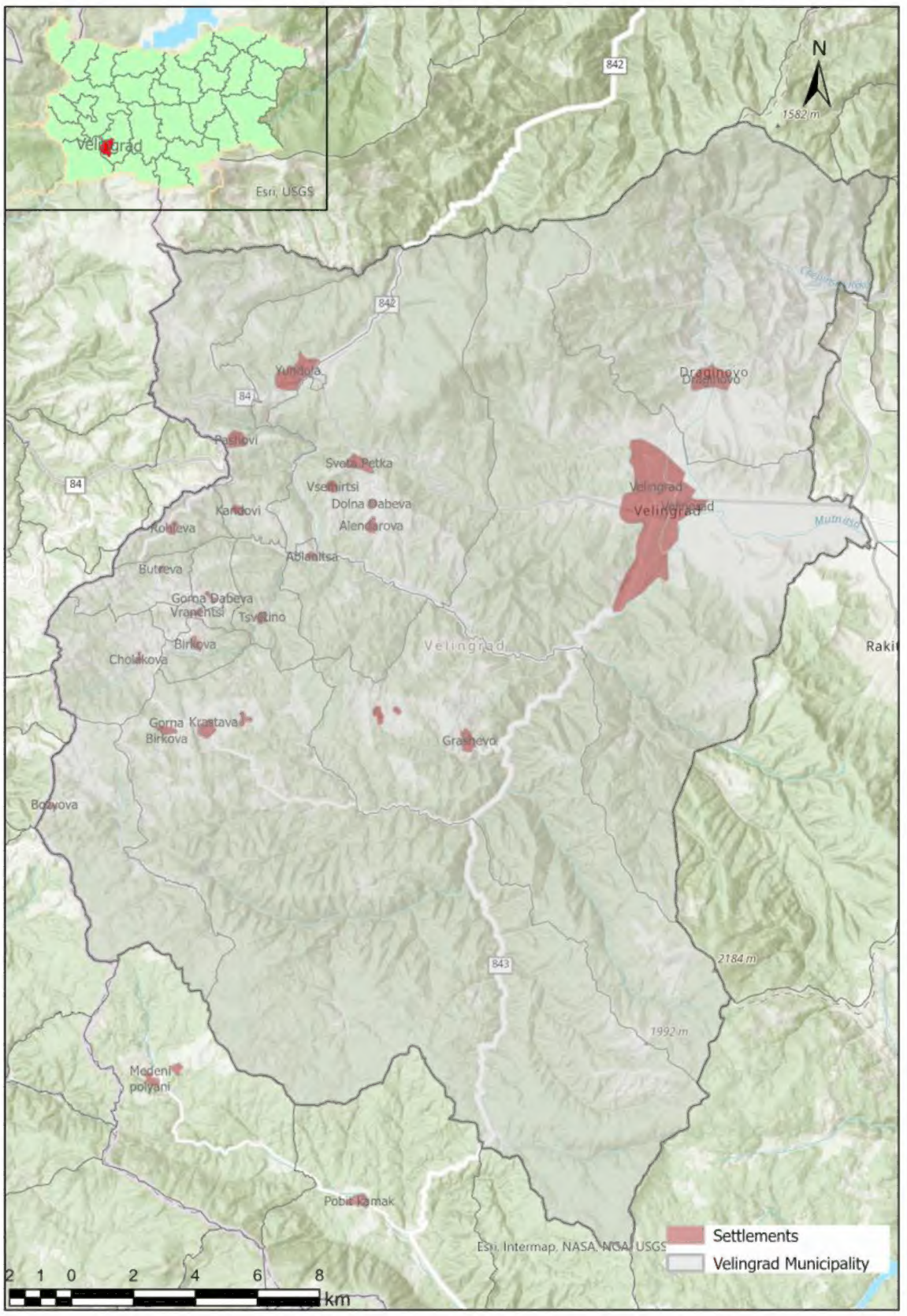

Figure 1. Study object – An overview of Velingrad municipality, Basemap: Google maps

tural specifics – they are predominantly Bulgarian Muslims (Pomak) that were forcefully converted to Islam in the 17th century (Aleksiev et al., 2002). They live in closed communities and have preserved many of the old traditions, typical customs, and close-to-nature way of life, while the town has a mixed population and is a famous spa center. Despite the ways of exploitation of the forests in the past and nowadays, forest management remains the main occupation of the local population (Aleksiev et al., 2002). The natural resources (forests and mineral springs) have to a big extent

determined the socio-economic development of the area and are a major factor for its profile today as well.

One of the important factors for the assessment of the vulnerability of modern socio-ecological systems to future human activities and climate change can be greatly improved by knowing the rates and directions of past trajectories in key processes (Petrosillo et al., 2015). In order to outline the cause-effect relationships that formed these processes, a retrospective review of the forestry sector and the economic development was done. Combining demographic, economic, and cultural factors, as well as the land use, the elements linking ecosystem services (ESs) and human well-being at fine scale (Zhang et al., 2021) are considered. Therefore, statistical data on demography, climate parameters and land use is analyzed to complete the analysis of socio-ecological connections. The demographic trends are considered indicative because they form the social aspect of the human-nature system and relate to the economic trends. Land use changes have both environmental and socio-economic impacts (Appelt et al., 2020) and are often a manifestation of socio-ecological changes. Climate fluctuations are also considered since local communities that are strongly dependent on natural resources are considered particularly vulnerable to climate change (Garcia del Amo and Junqueira, 2023).

The investigation was carried out in a series of well-defined, successive stages, each building upon the previous one, following a systematic, step-by-step approach.

A comprehensive survey of the existing literature was undertaken to collate the necessary data for this study. The research started with a literature review that covered sources that trace back the development of the forests (Alexiev et al., 2002; Diviziev, 2007; Tsanov, 2011; Tsanov, 2014; Panayotov et al., 2016). This information was supplemented with data from Forest management plans. Socio-economic information was obtained from local strategic plans and development programs – Plan for development of forests in the territory of Velingrad municipality; Municipal development plan 2007-2013, Integrated development plan of Velingrad municipality 2021-2027, Environmental protection program for the period 2021-2028. To complement the trends and conclusions, available statistical data for past periods was collected for population number and economic parameters –e.g. gross domestic product by sectors, manufactured product incomes, employment (NSI, 2024). All the information was processed and georeferenced. The land use data was gathered from two sources – the Land balance, provided by the National Statistical Institute and the Corine Land Cover data, compared for reference years 1990 and 2018. Data for water and air quality as well as for waste management was collected from recent monitoring reports (EEA, 2024).

The climate data was collected for the period 1975-2022 from statistical climate models (Visual Crossing Weather), including the daily temperature, precipitation and humidity values that were later summarized by pivot tables. The data was gathered for 8 locations, situated in the different parts of the municipality, and covering altitude from 777 m. asl to 1573 m asl. The data was gathered on a daily basis and processed by pivot tables to define the trends of main climate parameters. The mean annual temperatures for the selected locations for the period 1975 – 2022 were georeferenced and

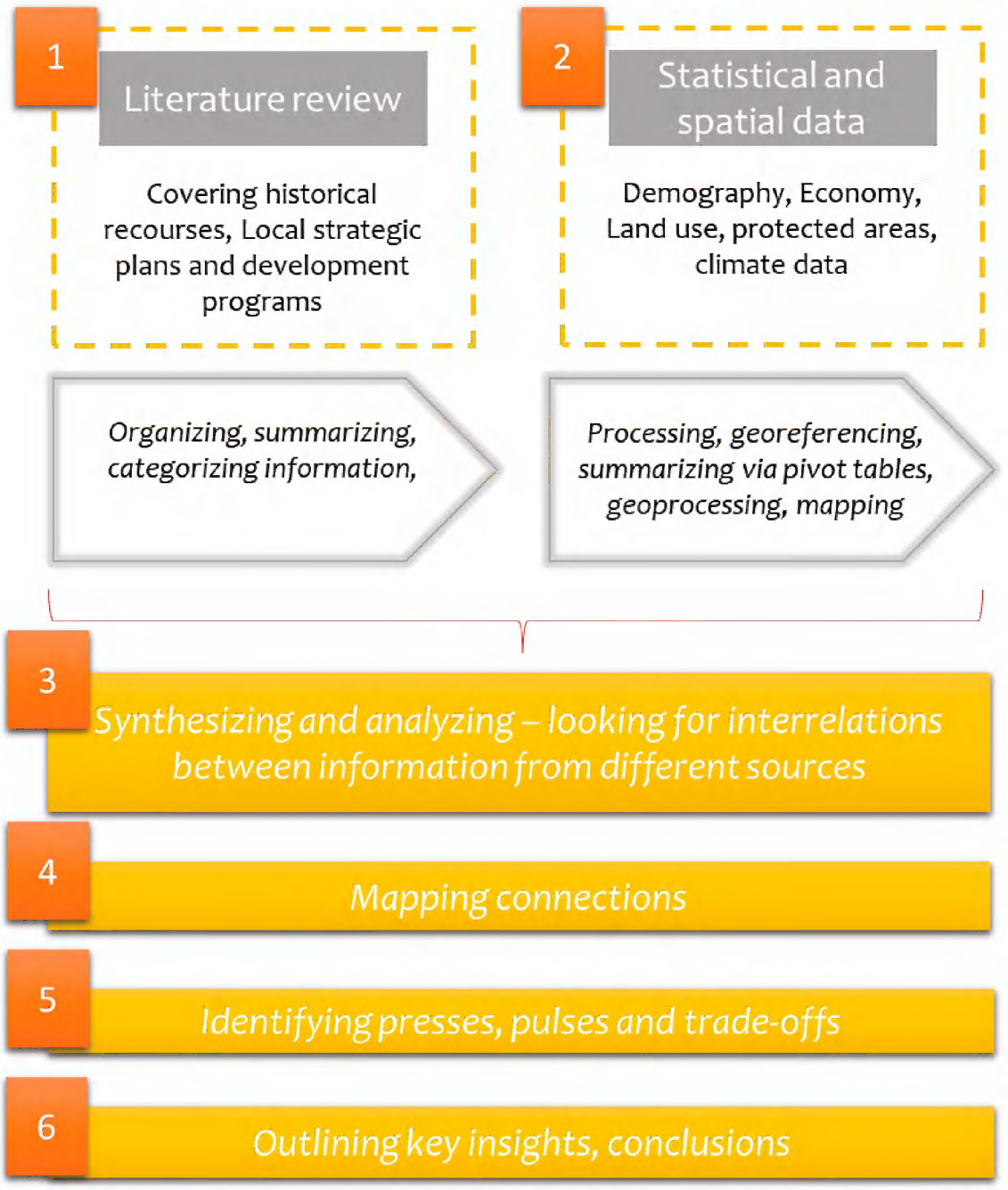
1
Literature review
Covering historical recourses, Local strategic plans and development programs
2
Statistical and spatial data
Demography, Economy, Land use, protected areas, climate data
Organizing, summarizing, categorizing information,
Processing, georeferencing, summarizing via pivot tables, geoprocessing, mapping
3
Synthesizing and analyzing – looking for interrelations between information from different sources
4
Mapping connections
5
Identifying presses, pulses and trade-offs
6
Outlining key insights, conclusions

Figure 2. Methodological workflow

interpolated using Inverse Distance Weighted Interpolation to visualize the patterns in the whole study area. The trends were juxtaposed with data from Meteoblue (2024). Anomalies for temperature and precipitation from Meteoblue (2024) were used to complete the results.

The data is very heterogeneous, and the different sources provided data with different resolution and time range. So, when overlaying the data, common trends could be outlined for the period 1985-2022. Nevertheless, the obtained data by components is reviewed in its original time-range in order not to lose any information.

All the data was synthesized and analyzed with focus on finding interrelations between information from different sources. Human well-being has a two-way interaction with ecosystem condition, mediated in one direction through the services that ecosystems provide to people, and in the other by the largely unintended impacts of human activities on ecosystem functioning (McMichael et al. 2005). In the present paper interrelations are identified in the form of linkages that exist in between

key components of the CHANS – ecological, economic, demographic, placing in the center forests. To simplify the approach, the presented linkages are unidirectional. The main aim is to identify interdependencies and patterns of behavior and reaction of the socio-ecological system to disturbances. Attempts to identify and assess linkages between human and nature have already been made, using different aspects, and chasing different goals (McMichael et al. 2005, Santos-Martín et al., 2013, Yang et al., 2015). The approach used in the present study is based on two stages – first, breaking down the leading economic sectors of the study area into input natural resources that they rely on, by again preserving the general idea to delineate the needs from the past decades from the contemporary ones and those in the villages from this in the town. Then comes the second stage where the ecosystem services, ecological problems and threats are included in an attempt to put all these key-role actors in one chart and draw the connections that exist and are best manifested by using different colors. The main ecological issues included in the chart are the ones outlined in the analysis of the strategic documents and analyzed statistics, i.e. water pollution, soil damage, air pollution, deforestation, biodiversity loss, solid waste pollution. The leading economic sectors are related both to the ecological issues that they contribute to and the ecosystem services that they rely on. The sectors related to the villages/town and those that are more relevant for the past or present are also indexed. The connections are drawn upon expert opinion. The purpose of the chart is to summarize the socio-ecological connections and to illustrate their complexity without going into further scientific assessment. To sum up all the findings, from the retrospective review, a table summarizing the periods with their main characteristics, environmental consequence and disturbances was prepared. To differentiate the disturbances, the press-pulse dynamic (PPD) framework (Collins et al., 2011) is used – where pulse events are relatively discrete and rapid while press events are sustained and chronic. The table includes also the slow and fast variables within the socio-ecological system that are changing under the influence of the drivers (Walker et al., 2012).

Results

The results presented include historical analysis of the forestry sector, economic changes over time, identified trends by key fields, maps of connections and a summary table of the changes over time.

Forestry sector – retrospection

The coniferous forests in the Western Rhodope Mountains have significant economic value for the country and therefore the forest administration set them on a very specific management regime (Tsanov, 2014). Historical facts from Konstantin Baykushev (end of XIX century) informed that the region was forested mainly with oak forests and oak mixed with pine, very degraded by logging (Panayotov et al., 2016). Since the start of

the railway construction in 1868, more than 2 million traverses have been cut from the oak forests. Forests near the railway were strongly degraded, followed by those near the rivers. In 1885, the railway line to Sofia was established, which again increased logging. As the population increased, large areas of forest were destroyed to create more agricultural fields. Most forests are cut down around the villages of Tsvetino, Sveta Petka, Krastava and along the Ablanitsa river. The steep slopes and torrential rains caused this field to turn into gulches and caused severe erosion in more than 8,500 acres of former forest lands (Tsanov, 2014). The first forest management plans in the region were elaborated in 1903 (Tsanov, 2011). During the First and Second World Wars, no afforestation was carried out (Tsanov, 2014), except first afforestation in 1911-1912 with purely decorative purpose. Very active afforestation followed – during the period 1945-1950, an average of 1,500 decares were afforested each year. These afforestation activities were realized with seeds, not saplings and until late spring. The new-formed saplings were not well managed so few of them survived. Erosion processes have been a big problem due to the steep terrains, big slopes and grazing. After 1951, afforestation is initiated with a new technology by making terraces and platforms that cross the path of water runoff during rain and thus cross the erosion process of the entire slope (Tsanov, 2014). From 1950 the average annual afforestation of 3,547 decares started, which reached 8,076 decares in 1960. For comparison, in 2012, 12,041 decares were planted in the whole country (Tsanov, 2014). On May 26, 1961, a strong wind vortex swept away the stands of the most valuable conifer plantations in the area on a territory of 2,800 hectares. In just 7 minutes, over one million cubic meters of wood fell. An active campaign to restore the felled plantations began in 1964. In 1977, the creation of 100,000 decares of new forests was announced. The volume of logging increased continuously during the period 1950-1975, which lead to deterioration of all functions of the forest. Mature and maturing stocks were cut down. These practices did not bear in mind that the renewal processes in the forests take place at different rates and with a different regularity (Tsanov, 2011).

Forestry and felling are changing over time, and currently the new principles for environmentally friendly and sustainable forest management in a mixed and multi-aged forest, composed of adapted local species, whose stock is qualitatively best and optimally high, are recommended (Tsanov, 2011).

Economy

The economic development of this region could be conditionally divided into 4 periods: 1. Ottoman empire – XIV to XIX century; 2. Beginning of the XX century; 3. Planned economy 1944-1989; Market economy 1989 – onwards.

In the first period (Ottoman rule XIV to XIX century) the inhabitants here were weavers, carpenters, and farmers. Later, in the second period, after the road from Pazardzhik field to Chepino was constructed, forestry was strengthened at the expense of the poor weaver business. Forests are the main source of livelihood and sustenance for the local population. The iron and steel crafts, as well as stonework, also took place.

Table 1. Employment by sectors by periods from 1932 to 2019

Employment 1932-1942	**Employment 2000 (Municipal development plan 2007-2014 Velingrad municipality)**	**Employment 2019 (Plan for integrated development Velingrad municipality)**
Agriculture – 84%	17,28%	Agriculture – 5.4%
Industry –1.3% Crafts 4.3%	33.51%	Industry – 24.7%
Trade – 4.3%	27,4% (tourism, trade, transport)	Services – 69,9%

Source: Alexiev, 2002, Municipal development plan 2007-2014 Velingrad municipality, Plan for integrated development Velingrad municipality

In the beginning of the XX century, agriculture becomes the main occupation of the locals and main source of income. Agriculture was based on growing rye, barley, corn, oats to potatoes, linen, and fruit. With infrastructural development the importance of forestry was strengthened. After 1949 the agricultural land is nationalized and united, agriculture is strongly developed as a national policy. In the period 1944 -1989 industry is strongly promoted by the political regime and along with agriculture and forestry formed a strong economic base in the region. Forests are the backbone of the economy in this period. In 1948 the woodworking plant „Georgi Dimitrov" (later Yundola-91) started working, processing 110 000 m^3 wood every year. Resin mining was an important industry, and in 1953 the "Crystal" factory was built, which produced balsamic rosin and balsamic turpentine. In 1959 a wooden toys factory is established. It was very successful and exported goods in the country and abroad. In 1960 the first workshop to produce particle boards started working and exporting its production abroad. Furniture production also flourished. The local population was widely occupied in forestry-related sectors either in the plants or as owners of small family workshops. This rapid development of the industry based on timber and timber products stimulated logging and is a prerequisite for exceeding the logging and disturbing the balance in the forests (Divisiev, 2007). Transport is also developed. The population takes an active part in afforestation and forest cultivation, felling, primary processing, and transportation of timber. The traditions in both secondary and higher education in forestry in the region are founded. The economic structure of this region has undergone several great changes. After 1989 agriculture decays – the farms and the processing plants are closed. Agriculture remains the main employment for the villages where single households grow crops and cattle mainly for personal needs. This reflects in land use change– diminishing arable land and increase of the barren lands. Many of the traditional industries such as mining and processing of marble and granite, production of wooden and laminated boards, production of kitchen furniture, metal cutting machines, extraction of aggregates building materials, asphalt production, flax processing,

weaving, cultivation of carnations and greenhouse vegetables closed after the transition of the country to a market economy. And these are all productions with negative effects on the environment. Due to the mineral water resources in the region the development of tourism starts. The transition to planned economy led to many structural changes that resulted in total decay of agriculture and industry. The tertiary sector takes precedence – the town economy starts to rely mainly on tourism and supporting trade. Tourism has turned into the dominant economic sector in the region, changing the urban structure of the town, drawing investments, popularizing the whole area and influencing the priorities, policies and funds allocation in the region. For the period 2014-2022 the number of people occupied in forestry and agriculture drops by 15% (NSI, 2024). Unemployment, especially among the young population, appears to be a problem. The villages remain dependent on agriculture, logging, and non-timber products – forestry sector, small-scale livestock breeding and picking forest fruits and mushrooms are the main occupation for the population.

Demography

The demographic analysis is based on the number of inhabitants by settlements, following the trends from 1985 to 2022. The data is derived from the National register of populated places (National Statistical Institute, 2024) that uses both data from census and current statistics. For some of the settlements the number of inhabitants is available since 1934, but since some of them were formed later, or transformed into bigger or smaller settlements, the line of data is straightforward and comparative for the chosen period (1985-2022).

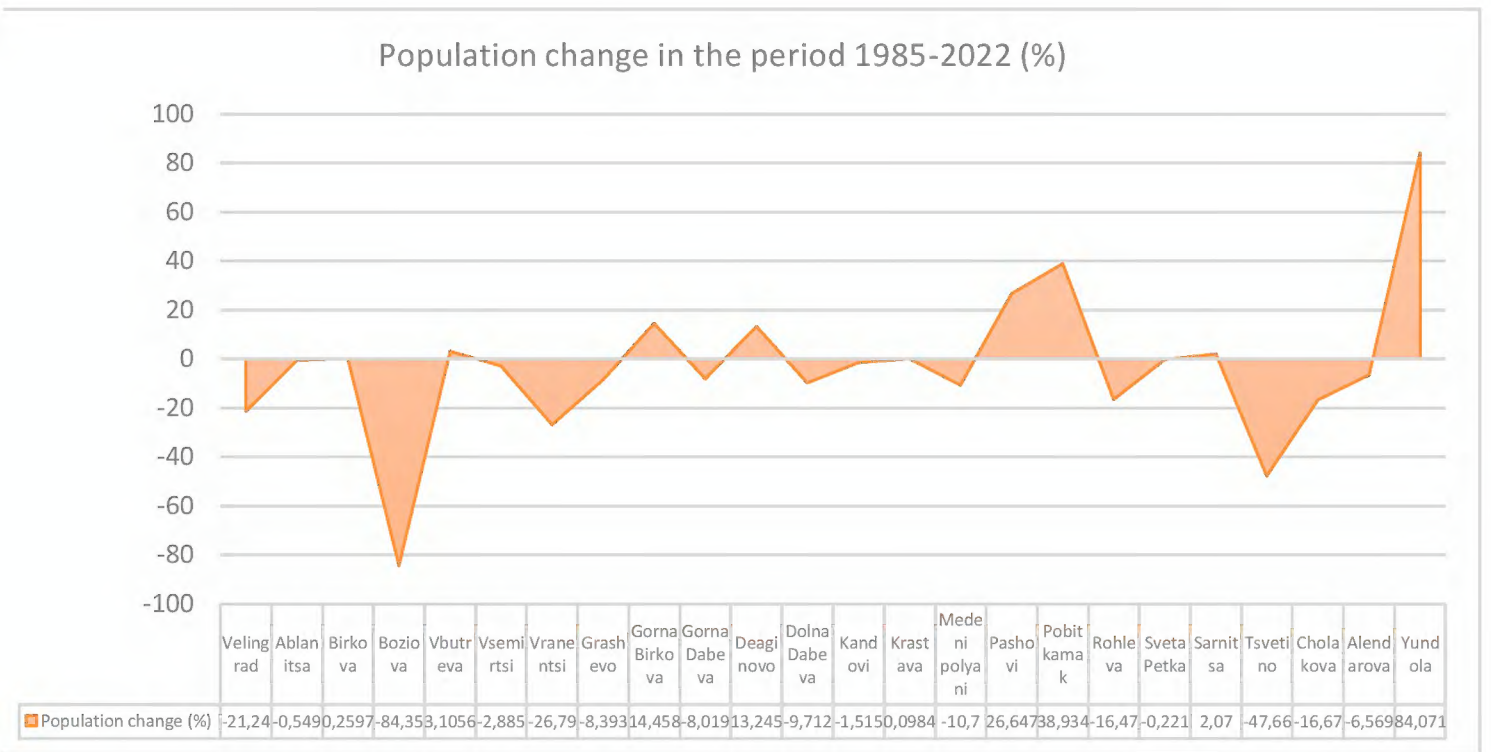

Figure 3. Demographic trends – population numbers for the period 1985-2022, ***Source:*** *National Statistical Institute*

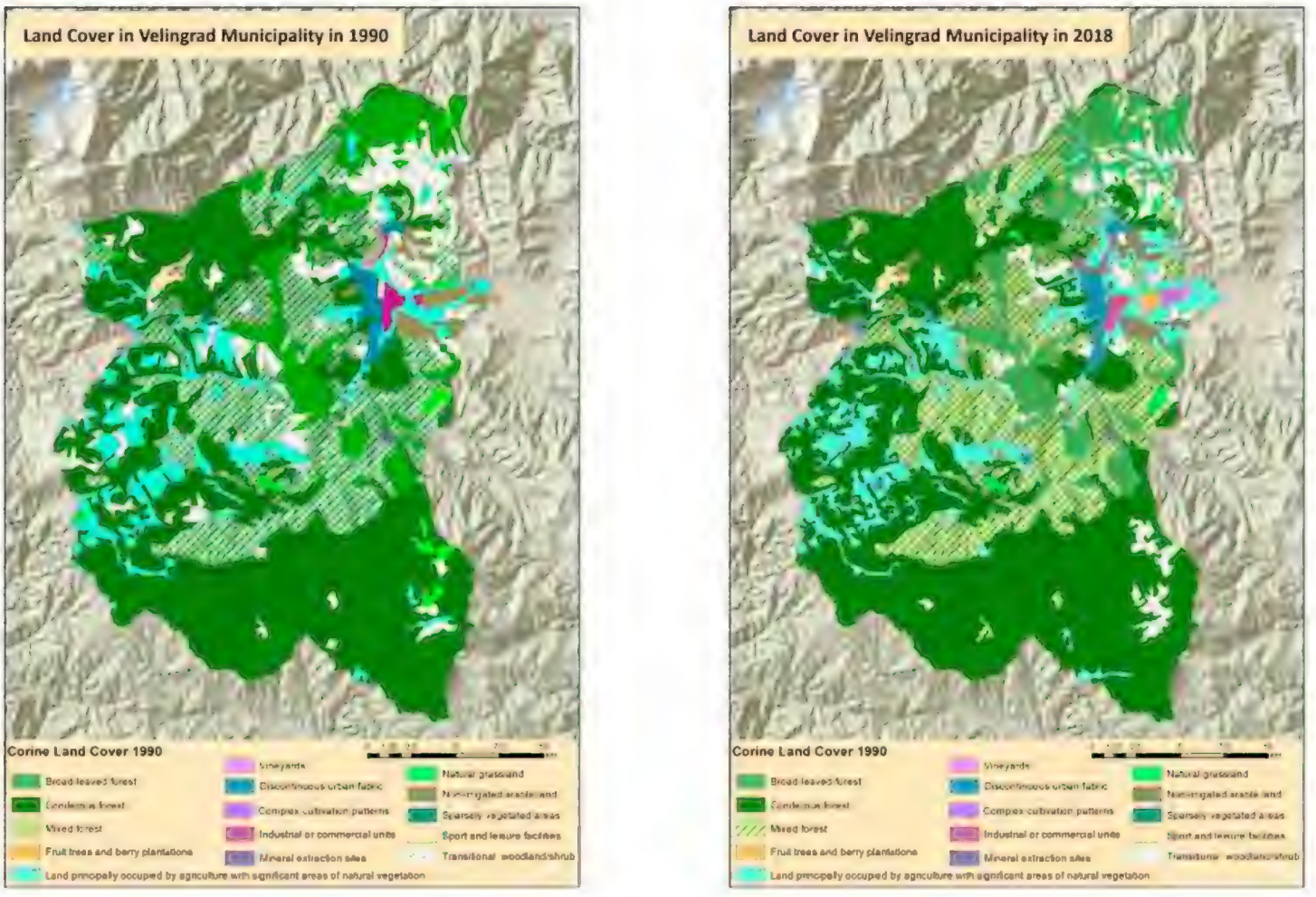
Land Cover in Velingrad Municipality in 1990
Corine Land Cover 1990
Land Cover in Velingrad Municipality in 2018
Corine Land Cover 1990

Figure 4. Corine land cover 1990 vs. 2018, *Source: Corine land cover 1990 and Corine land cover 2018*

Table 2. Changes in land use according to Corine land cover 1990 vs. 2018 *Source: Corine land cover 1990 and Corine land cover 2018*

Land Cover	1990 (ha)	2018 (ha)	Difference (%)
Broad-leaved forest	5595.516568	5686.903	1.63321638
Coniferous forest	27897.97999	29043.09	4.10464419
Discontinuous urban fabric	648.85421	789.4571	21.6694047
Fruit trees and berry plantations	26.944649	130.6747	384.974731
Industrial or commercial units	262.925972	158.0244	-39.897771
Land principally occupied by agriculture, with significant areas of natural vegetation	5449.818071	6995.914	28.3696825
Mineral extraction sites	30.280098	26.00884	-14.10582
Mixed forest	13020.96493	12529.19	-3.7768092
Natural grasslands	715.061376	496.4974	-30.565766
Non-irrigated arable land	893.370517	773.1756	-13.454099
Sport and leisure facilities	212.417053	182.1859	-14.232003
Transitional woodland-shrub	5299.023953	3422.262	-35.417121

Land use

According to the data from NSI, the main changes are in the agricultural land – in 2021 decrease with 4% compared to 2000, while only 0.4% decrease of forest territories for the same years. A significant part of the arable land – 20,5%, is not permanently cultivated.

The results from Corine Land Cover show similar results in terms of agricultural land – increase in land principally occupied by agriculture, with significant areas of natural vegetation land and decrease in non-irrigated arable land with more than 13%. The broad-leaved (+1,6%) and coniferous (+4,1%) forests show a slight increase, while the mixed forests decrease (-3,7%).

The allocated grazing areas for domestic animals are not effectively used because of the lack of enough animals. It must be considered that the release of domestic animals into grazing plantations always results in their disruption to a greater or less extent (Tsanov, 2011).

Perennial Climate Regimes

Climate models show a warming trend for the period 1975-2022 (Figure 5).

Variations were observed over the years with lowering and increasing the mean annual temperatures, but a significant raise of the mean annual temperature is observed for that period.

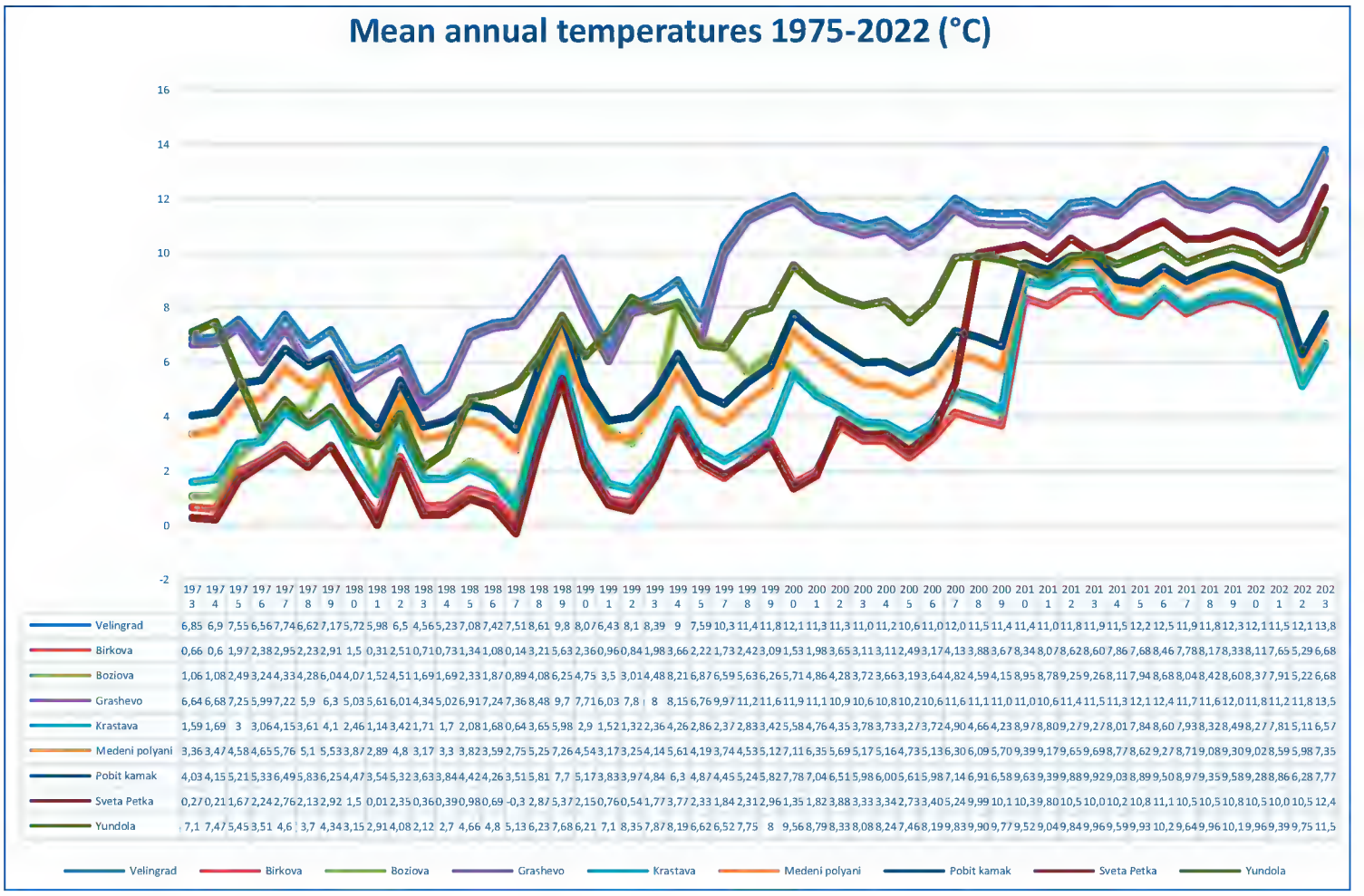

Figure 5. Mean annual temperatures 1975-2022 (°C) in Velingrad Municipality. *Source: Visual Crossing Weather, 2023*

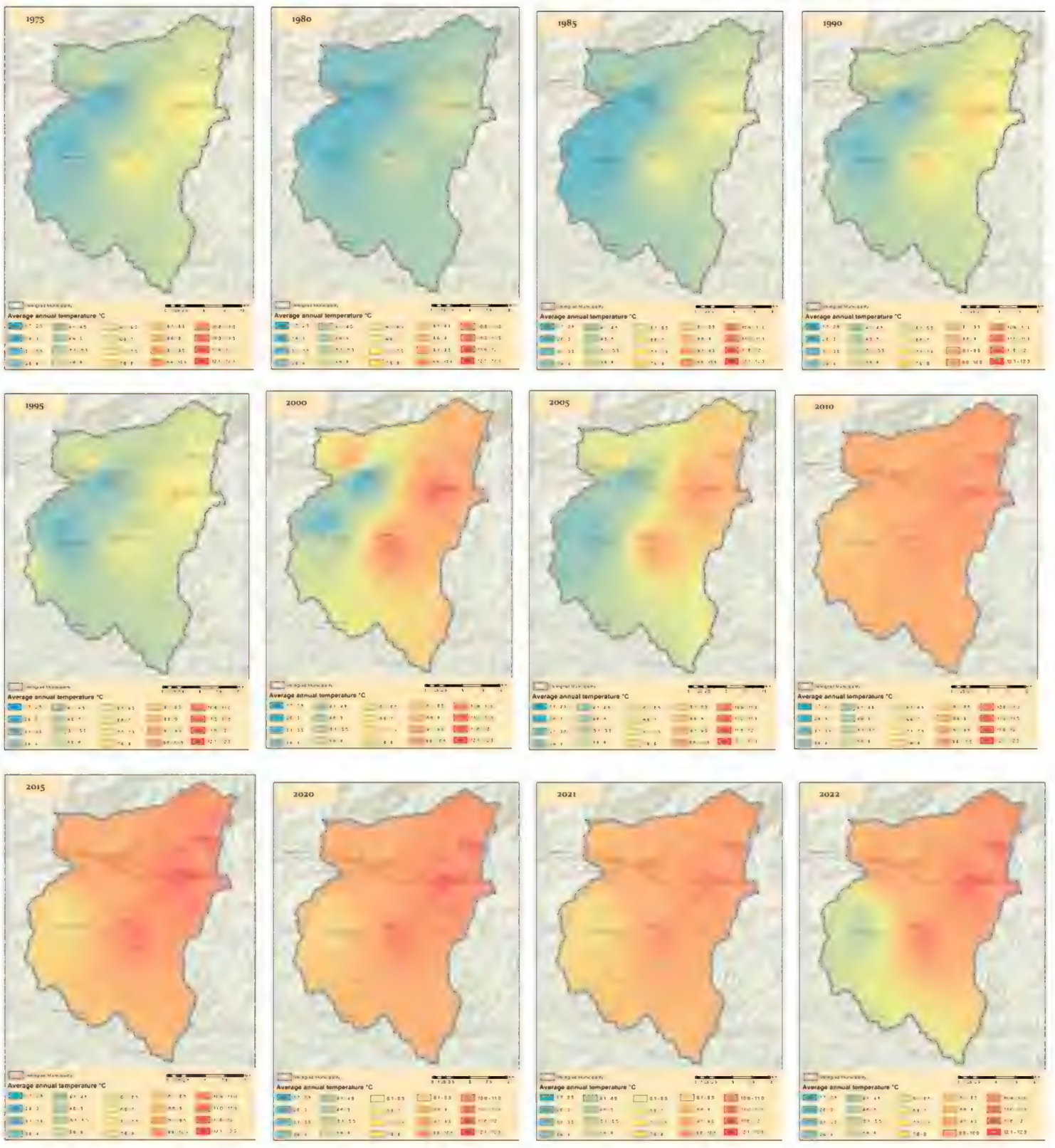

Figure 6. Mean annual temperatures 1975-2022 (°C) in Velingrad Municipality. *Source: Visual Crossing Weather, 2023*

Nevertheless, climate models indicate a warming trend for the period 1975-2022 (Fig. 5 and Fig. 6).

Besides the warming tendency observed, harmful abiotic impacts on the forests occur due to abnormal climate deviations. This includes extreme temperatures (frost), atmospheric precipitation (snow, frost, hail), atmospheric air movement (strong storms, thunder) (Tsanov, 2014). In the Western Rhodopes an increase in extreme weather events and shifts in climate like a decrease in cold temperature

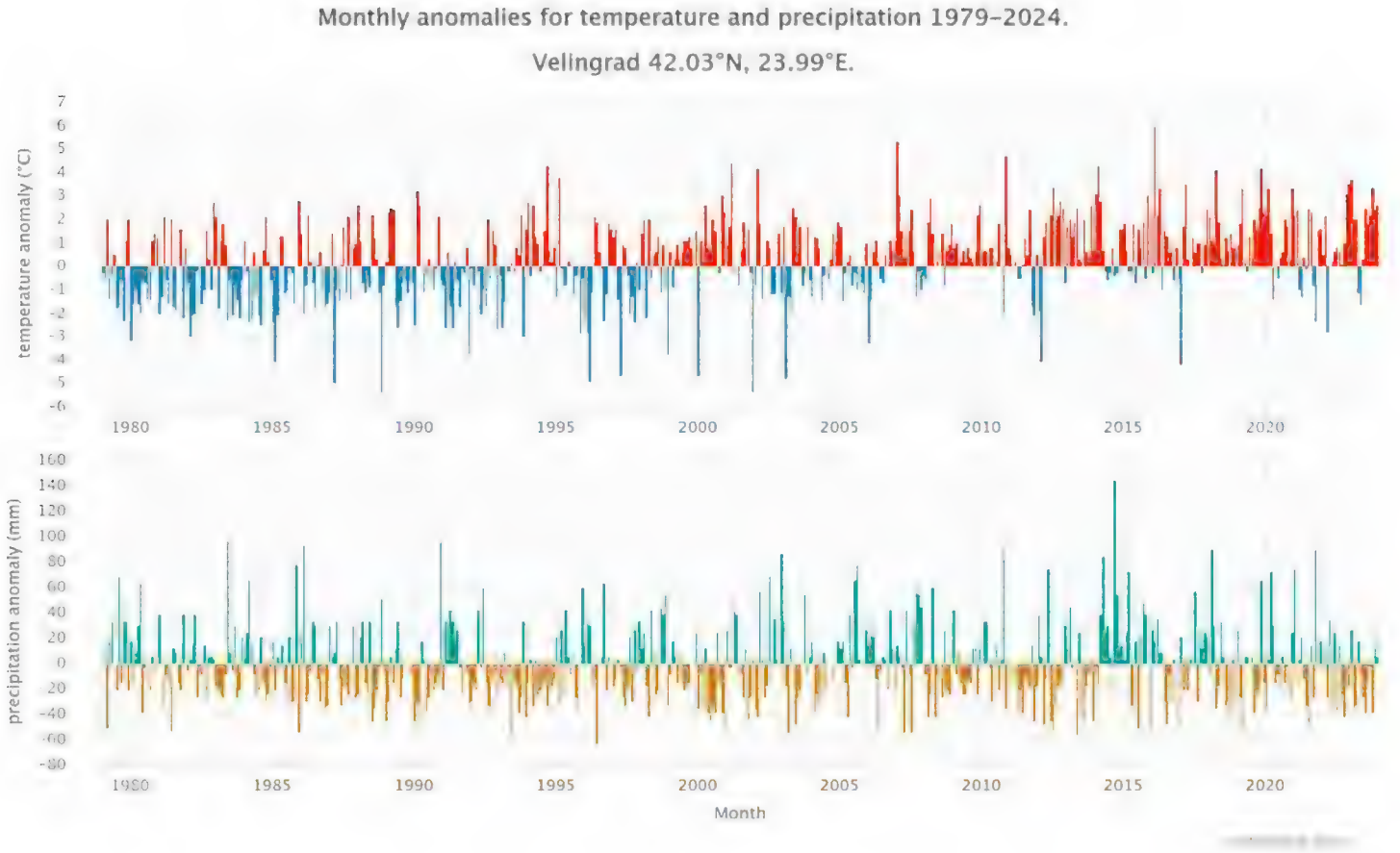

Figure 7. Monthly Anomalies of Temperature and Precipitation – Climate Change Velingrad. *Source: Meteoblue, 2024*

extremes, an increase in warm temperature extremes, an increase in the duration of summer dry periods, and an increase in the number of heavy precipitation events have been observed (Zlatanov et al., 2017). According to climate models, the extremes happen more often and increase their peaks in the last ten years.

This information can contribute to understanding a system's disturbance regime and indicate the need for alternative forest management practices.

Water and air monitoring

Surface waters are monitored at a point for the Chepinska River after the town of Velingrad. According to reports from East Aegean River Basin Directorate, for the period 2014 – 2017, a bad ecological condition was established in terms of biological quality elements – benthic macroinvertebrate fauna. The reason for the bad condition is the discharge of untreated household-fecal wastewater from the settlements. At the Chepinska river point after the town of Velingrad, exceeding the standards for good condition according to Biological oxygen demand (BOD), ammonium nitrogen, nitrate nitrogen, total nitrogen, total phosphorus and orthophosphates are monitored.

There are no sewage treatment plants in the populated areas of the municipality. Industrial wastewater discharges into surface water intakes, about 80% of it is treated in local treatment facilities.

Exceedances of the average nightly norms for the concentration of PM10 in the atmosphere have a highly pronounced seasonal character – they are only during the heating season (Executive environmental Agency, 2024)

Almost all the generated waste is landfilled. No pre-treatment of the waste is carried out. The municipality of Velingrad does not fulfill the goals for recycling household waste. Separate waste collection and construction waste collection systems are not efficient enough (Velingrad municipality, 2020).

Connections

The dependence on local resources in the last two periods (1944-1989 and 1989-now) is investigated, breaking down the dependence on the natural resources of the economic sectors separately for the town and for the villages.

This breakdown is used to build the connections between the economy and local resources. To complete the analysis, the main ecological issues were outlined, using the Programs for environmental protection of forest development of the municipality. The economy sectors are also related to the main ecosystem services and their social meaning. The economic sectors are marked whether they are important for the town or the villages and whether it was developed in the past or is also a leading sector in the present.

In the center of the relations are placed the economic values. The relations are colored according to the ecosystem services that feed them to illustrate the strong dependence on the local resources. The ecological issues are presented in terms of the pressures they experience because of the economy and the external and internal pressures from other origins. Positives are also outlined, again listing both those from the past and those from the present.

Social-ecological systems also undergo change over time. Understanding what is behind these changes—the change drivers—can provide insight into how historical system dynamics have shaped the current focal system and what effects they might have in the future. A historical profile of the system can also reveal changes in system resilience over time, including those that occur in response to specific human interventions, whether intended or not (Resilience Alliance, 2010.).

Table 3. Dependance on the economic sectors on local resources

	Economic sector	**Natural resources**	**Economic sector**	**Natural resources**
	Town		Villages	
1944 -1989	marble and granite, production	Stone resources	agriculture,	Soils, climate, water
	wooden and laminated boards	Forests	collecting herbs, mushrooms	Forests
	production of kitchen furniture	Forests	Logging	Forests
	metal cutting machines,	external raw materials	fodder crops, potatoes,	Soils, climate, water
	extraction of aggregates building materials	Local resources, rivers	sheep breeding, cattle breeding	Soils, climate, water
	asphalt production	external raw materials		
	flax processing	Agriculture (soils, climate, water)		
	chemical industry	external raw materials		
	mechanical engineering	external raw materials		
	cultivation of carnations and greenhouse vegetables	Agriculture (Soils, climate, water)		
	Tourism	Mineral water, Forests		
	Town		Villages	
1989 – present days	Tourism	Mineral water, Forests	agriculture,	Soils, climate, water
	carpentry, woodworking, furniture production	Forests	collecting herbs, mushrooms	Forests
			Logging	Forests
			fodder crops, potatoes,	Soils, climate, water
	bottling of mineral water	Mineral water, forests		
	wood pellet production	Forests		
	food industry	Local and external resources		
	power supply from mini hydroelectric plan	Water		

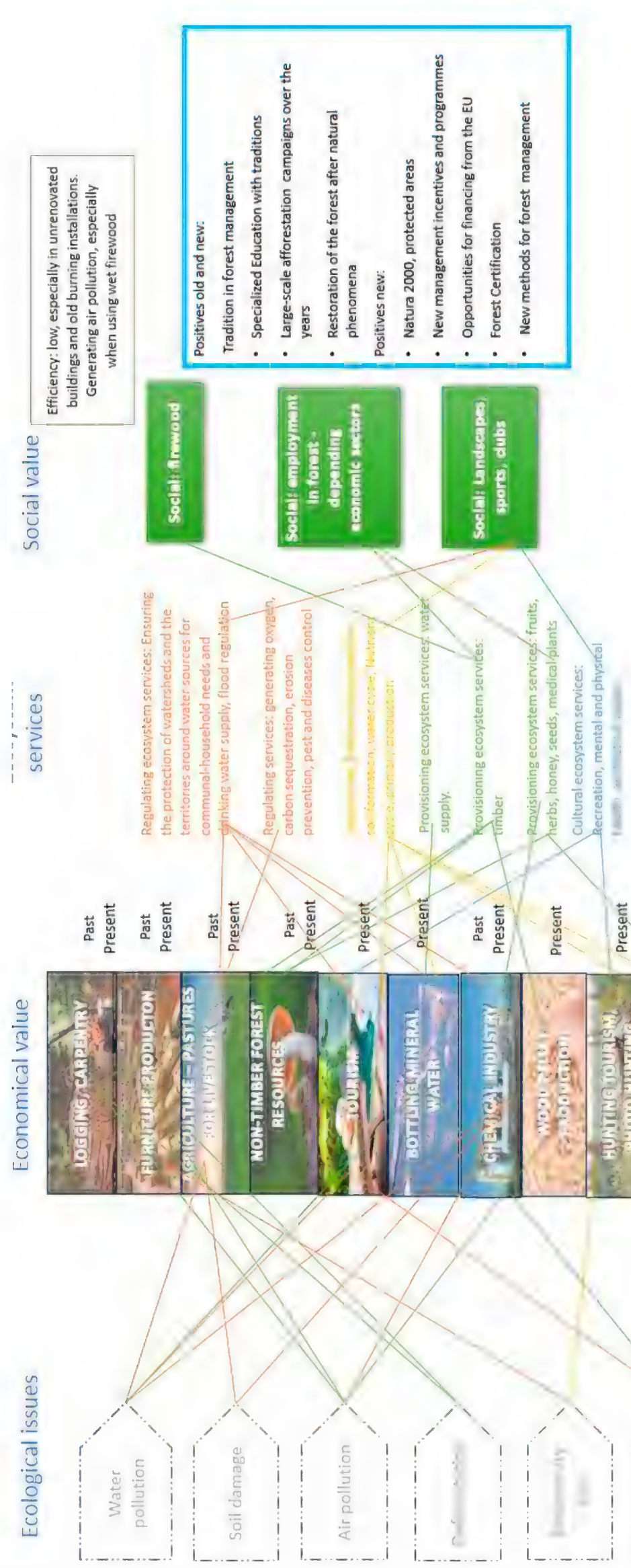
Social value
Efficiency: low, especially in unrenovated buildings and old burning installations. Generating air pollution, especially when using wet firewood
Social: firewood
Social: employment in forest - depending economic sectors
Social: landscapes, sports, clubs
Positives old and new:
Tradition in forest management
• Specialized Education with traditions
• Large-scale afforestation campaigns over the years
• Restoration of the forest after natural phenomena
Positives new:
• Natura 2000, protected areas
• New management incentives and programmes
• Opportunities for financing from the EU
• Forest Certification
• New methods for forest management
Regulating ecosystem services: Ensuring the protection of watersheds and the territories around water sources for communal-household needs and drinking water supply, flood regulation
Regulating services: generating oxygen, carbon sequestration, erosion prevention, pest and diseases control
Provisioning ecosystem services: water supply.
Provisioning ecosystem services: timber
Provisioning ecosystem services: fruits, herbs, honey, seeds, medical plants
Cultural ecosystem services: Recreation, mental and physical
Economical value
Past
Present
LOGGING, CARPENTRY
FURNITURE PRODUCTION
AGRICULTURE – PASTURES
NON-TIMBER FOREST RESOURCES
TOURISM
BOTTLING MINERAL WATER
CHEMICAL INDUSTRY
HUNTING TOURISM, PHOTO HUNTING
PRODUCTION OF HONEY AND BEE PRODUCTS
Ecological issues
Water pollution
Soil damage
Air pollution
Solid waste pollution

Figure 7. Interrelations between economy, ecosystem services, ecological issues, and social values

Table 4. Summary of the disturbance in CHANS and the changing variables after 1885

Period	Characteristics	Environmental Consequences	Disturbances (Presses and pulses)	Changing variables
Around 1885	Cutting down trees for railroad building	deforestation, biodiversity loss -elimination of the oak forest	Press	Biodiversity Infrastructure – connections improved
Around 1911	Clearing land for agriculture also using forest fires	Deforestation severe landslides on 8,500 acres of lands that were former forests. 9000-acre forests destroyed by forest fires	Pulse, pressure	Land-use change Biodiversity Erosion Agriculture and livestock breeding development Population increase
1950-1977	Forest management	Extensive afforestation – planting with species that are not in their original ecological niche	Change in ecosystem	Land-use change Changing structure and area of the forest Creating valuable coniferous forests
1961	Strong wind	Destroying vast forest area. Many fallen trees, prerequisite for calamities	Pulse	Destroyed forest
1950-1975	Active use of forests for timber	Deforestation	Press	Intensive development of the secondary sector Active forest management Education in forest management Active participation from the local population Grazing
After 1989	Change of economic profile	Illegal logging Calamities Pollution Biodiversity loss	Press (tourism)	Change of forest management practices Climate extremes happen more often Extensive usage of the forest and water resources Pollution – water (solid waste) and air Less people occupied in forestry and agriculture Intensive natural processes of thinning and degradation in the plantations Succession processes towards restoration of autochthonic vegetation

Discussion

Coupled human-natural systems are experiencing unprecedented rapid changes and progressively tighter couplings at multiple scales (Liu et al., 2021). Being aware of critical thresholds between state of the system can potentially provide advances warning of impending change as well as opportunities for preventing undesirable shifts in these states of the system. A broad overview of system change through time can reveal patterns of past disturbances and responses as well as the impacts of cumulative or gradually changing variables (Resilience alliance, 2010). The retrospective analysis of the interactions between forests and people in Velingrad Municipality shows periods of serious disturbances. The uncontrolled logging caused a regime shift from deciduous to coniferous forests. The deforestation caused disruption not only to the ecological system but also had a significant effect on the socio-economic system with the formed landslides which threatened the fields and houses of local people – that is a typical example of a trade-off in the socio-ecological system. Synergies were also formed, for example the community-based afforestation of the region had a tremendous impact on the contemporary landscape, but also formed attitudes towards forest. The massive forest planting marks the growth phase of the adaptive cycle of the socio-ecological system (Walker and Salt, 2006). Proof in this regard is the reaction to pulse disturbances like the strong wind vortex in 1961 which caused great ecological stress. The capacity of the socio-ecological system to absorb that stress was demonstrated with the extremely adequate and well-organized reaction of the forest administration which managed to clean the damaged land to avoid calamities and to afforest for ecosystem recovery. With time, the system's components become more strongly interconnected, its internal state – more strongly regulated. The system moved into its conservation phase. The interconnections of the socio-ecological system strengthened with the strong dependency of the local economy on forests, the specialization of the education system on the forestry sector. The social effect imprinted the way of life of the local population. A good example of these dependencies is the trade-off formed during the economic crisis in the years of transition to a market economy after 1990, when the exploitation of forests in the Velingrad region became the main alternative to the recession and a means of economic and social survival of the region. This leads to certain violations in the balance of the forest territories, as well as to an increase of illegal logging. Illegal logging among the Roma population reached particularly alarming proportions (Alexiev, 2002). This confirms McMichael et al. (2014) suggestion that in places where there are no other social safety nets, diminished human well-being tends to increase the immediate dependence on ecosystem services. Understanding the significance of a system's internal connections, its capacity to respond to disturbances and how these aspects change from phase to phase contributes to resilience thinking (Walker and Salt, 2006). The retrospection helped get a new look on the socio-ecological relations, their formation and adaptation over time. This notion, together with an overview of the contemporary presses and pulses that the system is expereincing support for better understanding the on-going processes and for a

proper management of forest resources. Forests are a critical component of the socio-ecological system. They regulate climate, ensure water supply, water balance, water protection and soil protection and have environmental, sanitary, and hygienic functions. Moreover, the forest vegetation in the area is a valuable source of wood, fodder, food products, medicinal plants, etc. (Environmental protection plan, Velingrad)

The pulses and presses with internal origin are tightly related with the population and economy. As populations and consumption levels grow, human-caused disturbances can intensify, with consequences for a system's general resilience (Resiliance Alliance, 2010). Therefore, the general trends for population number and the economic profile are analyzed with regard to possible disturbances. The demographic trend shows a constant population loss and disrupted age structure in town, while the small villages (apart from Boziova) have a very steady population number, some of them even show a slight increase. Nevertheless, we can conclude that the number of people in terms of local population is not a stress factor for the environment.

The economic changes reflected on the CHANS – closing the factories that forced the secondary sector lowered the pressure on the ecosystems, especially reducing the emissions to the atmosphere and water ecosystems, waste generation and resource consumption. Meanwhile the development of tourism has brought new challenges. The number of residents in the town decreases, but the number of people that benefit from the local ecosystem services actually increases because of the increasing number of tourists. This is linked to intensified traffic, more use of water, more load on the sewer system, more generated waste, construction, and urbanization. The lack of efficiency of the use of the resources, the poor infrastructure and the intensifying use of the resources leads to growing ecological issues, mainly in terms of water, air and solid waste pollution. Regarding forests the illegal logging is still a problem. It reduces the quality of forest ecosystems and can lead to disruption of the natural water balance in the entire area and trigger erosion and landslide processes (Plan for development of forests in the territory of Velingrad municipality). These internal pressures are combined with the climate regime fluctuations and the observed climatic extremes. Diamond (2005) includes climate changes as one of 5 main reasons that have contributed to or even led to the collapse of societies in the past. It is a factor that strongly influences each component of the system, no matter if it is anthropogenic or natural. One of the most vulnerable components of the environment is forests. Exceptionally the complex combination of different elements of forest ecosystems, a large part of which live, implies serious uncertainties given how they will be with projected higher temperatures and especially summer droughts over the next century (Panayotov et al., 2023). The extreme temperature strongly influences the condition and growth of the tree species. The late spring colds damage the flowers, leaves and twigs of the more sensitive species and the early autumn colds – the non-woody shoots of the species with longer vegetation period. The high summer temperatures cause dehydration of the cells, burning of the leaves, twigs or the bark of some species (Yurukov and Panayotov, 2015). Norway spruce is a cold-resistant tree species that can withstand low winter temperatures, but often suffers from late spring frosts. In some areas with a

large altitude in the central parts of the Western Rhodopes (for example, the area of Beglika) such sharp colds in late spring and early summer are the cause of the death of seedlings and damage to young trees (Panayotov et al., 2016). Currently, most of the coniferous plantations in the Western Rhodope Mountains exceed 40-50 years of age. Due to their low resistance, accelerated processes of deposition and degradation occur in them. Intensive succession processes have begun in the direction of restoration of the natural deciduous vegetation (Popov et al., 2018). The gradual change in climate conditions reduces the resistance of forest stands and makes them susceptible to pest attacks (Georgiev et al., 2022). Given the fact that most of the mature plantations are located at a higher altitude, the rise in temperatures will shift the isotherm lines in height, which will create conditions for insects to affect new forest areas. As a result, the riskiest vertical range will widen, and with it, increased risk can be expected from the occurrence of natural disturbances (Tsvetanov and Karabov, 2020). According to the White paper: Adapting to climate change: Towards a European framework for action, the consequences of climate change for forests are likely to include changes in their condition and productivity, as well as changes in the geographic range of some tree species. Measures have already been taken in this regard as production of saplings of tree species for afforestation that are adapted to the expected climate changes is planned (Plan for development of forests in the territory of Velingrad municipality). However, alternative management practices, tailored to the stands location on the landscape and its management history may be needed (Zlatanov et al., 2017).

The attempt to draw the relationship between the key components within the CHANS supports identifying the direction and magnitude of the influences the components exercise on one another and how the changes and trends reviewed so far influence them. The analysis shows that all key economic sectors rely on local resources. Apart from economic value, they also possess very strong social significance – both satisfying vital needs of the local population and laying in the deep foundation of their customs, traditions, and way of life. These relations are so stable that they have proven themselves over time, including during periods of political and structural change.

The present research makes a quick review of the present and past state of key components of the CHANS without going into in-depth analysis separately. Due to the wide diversity and number of components and interactions the analysis is based on the perception that the systems approach is holistic and focuses on how key components contribute to the dynamics of the whole system (Resilience Alliance, 2010). The component of the CHANS that are considered are not comprehensive enough to reveal the overall complexity of the connections in the system The population number is analyzed but more thorough research is recommended considering the effects of the ethnographic, age and educational structure of the population. The ethnic specifics in the research area are tightly related to natural resources and this is an aspect worthy of investigation. Apart from the rising temperature, the amount of precipitation and the humidity are also important parameters that should also be studied in future research. Another important aspect that influences the socio-ecological system and needs to be more thoroughly considered in the retrospection

is the political situation and policy of forestry and related sectors. The time period of the available statistical and literature data for the components do not overlap which hinders the analysis.

Conclusions

Although the structure of the economy has undergone some changes and diversification, the economic and social life in the Velingrad Municipality area is dependent on the local natural resources and has been entirely relying on them now and in the past. The results of the study lead to the conclusion that the local ecosystems are experiencing a hard time due to several exogenous and endogenous threats acting all at once. The additional pressure can damage the capacity of local ecosystems to deliver services, and this capacity can decline to such a degree that the probability of disaster or conflict increases (McMichael et al., 2005). The retrospection showed that the coexistence of humans and nature in the studied area has undergone different stages but has managed to adjust and stabilize itself. The ongoing disturbances nowadays (both pressures and pulses) cause many slow variables to accumulate and generate trade-offs that may lead to traps if not attended on time. The socio-ecological system seems to be in its conservation phase, where components become more strongly interconnected, the system itself becomes more and more rigid and resilience declines (Walker and Salt, 2006). Examples from the past suggest that the CHANS possesses its own homeostasis and demonstrated great resilience after the strong wind vortex from 1961. The dedicated forest management played a crucial role for the ecosystem recovery then. This raises the question, if now, in the next stage of its adaptive cycle, a pulse like that occurred, the system would withstand. The local authorities are already aware of some of these problems the Plan for development of forests in the territory of Velingrad municipality suggests adequate measures in forest management practices. But it also points out many problems that the contemporary forest management experiences, mainly in terms of organization and legislation. The plan is elaborated in 2015 and the problems identified are still relevant today. Degradation of environmental resources on which livelihoods depend is seldom intended as such but is an outcome of the cumulative effect of people's individual behavior (Boonstra et al., 2014). The local administration and population need to be aware of all the problems and threats of the system they are part of and become part of their solution.

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